**AS Unit 1: Basic Biochemistry and Cell Organisation**

|  |  |
| --- | --- |
| Name: | Date: |

**Topic 1.3 Cell Membranes and Transport – Page 2**

l. **Transport Across Membranes**

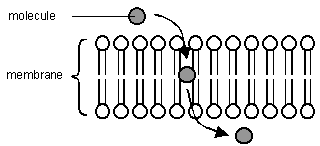
|  |  |  |
| --- | --- | --- |
|  |  | Completed |
| 1. | Look at the PowerPoint Cell Transport |  |
| 2. | Read about the transport of materials across membranes   * Rowlands p38-42 * Toole p * Hand-out 1.3c Transport Across Membranes * Hand-out 1.3d The Cell Surface Membrane Factsheet * Hand-out 1.3e Active Transport * Hand-out 1.3f The Fluid Mosaic Model |  |
| 3. | Assessed Homework   * Complete the essay on the transport of substances across membranes |  |

## Movement across Cell Membranes

Cell membranes are a barrier to most substances, and this property allows materials to be concentrated inside cells, excluded from cells, or simply separated from the outside environment. This is compartmentalisation and it is essential for life, as it enables reactions to take place that would otherwise be impossible. Eukaryotic cells can also compartmentalise materials inside organelles, this enables the cell to create optimal conditions for different reactions occurring within the cell. Obviously, materials need to be able to enter and leave cells, and there are five main methods by which substances can move across a cell membrane:

1. Diffusion
2. Osmosis
3. Facilitated diffusion
4. Active Transport
5. Endo and Exocytosis

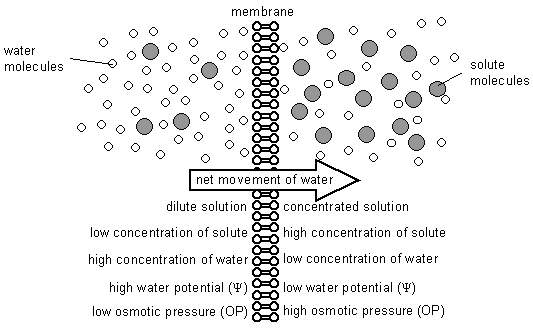
### 1. Diffusion



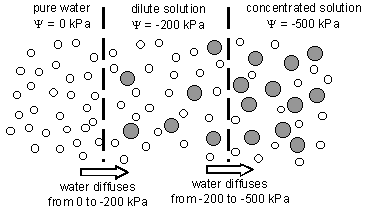
A few substances can diffuse directly through the lipid bilayer part of the membrane. The only substances that can do this are **lipid-soluble** / **non-polar** molecules such as steroids, or very small polar molecules such as and H2O and uncharged molecules such as O2. For these molecules the membrane is no barrier at all. Since diffusion is (obviously) a passive diffusion process, no energy is involved and substances can only move down their concentration gradient. Diffusion across the membrane phospholipid bilayer cannot be controlled by the cell, in the sense of being turned on then off.

### 2. Osmosis

Osmosis is a special type of diffusion that describes the movement of **water** across a membrane. It is in fact just normal diffusion across the lipid bilayer, but since water is so important and so abundant in cells (its concentration is about 50M), the diffusion of water has its own name - osmosis. The contents of cells are essentially solutions of numerous different solutes, and the more concentrated the solution, the more solute molecules there are in a given volume, so the fewer water molecules there are. Water molecules can diffuse freely across a membrane, but always down their concentration gradient, so water therefore diffuses from a dilute to a concentrated solution.



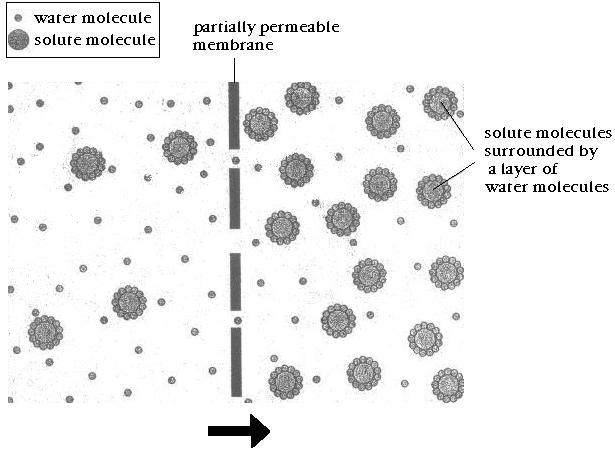
**Water Potential**. Osmosis can be quantified using water potential, so we can calculate which way water will move, and how fast. Water potential (Ψ, the Greek letter psi, pronounced "sy") is simply the effective concentration of water. It is measured in units of pressure (Pa, or usually kPa), and the rule is that water always "falls" from a high to a low water potential (in other words it's a bit like gravity potential or electrical potential). 100% pure water has Ψ = 0, which is the highest possible water potential, so all solutions have Ψ < 0, and you cannot get Ψ > 0.



**Water potential** is a measure of the pressure that water molecules exert on a membrane. The higher the concentration of water molecules the higher the pressure they exert and the higher the water potential. Pure water has the greatest concentration of water molecules and therefore will exert the highest water potential. The value of the water potential of pure water is zero. As all other solutions have a water potential less than this, they have negative values. For example a sucrose solution will have lower or more negative water potential that distilled water. The more concentrated a solution; the lower (or more negative) is its water potential. If you get confused with this think about temperature, a temperature of -150C is lower or more negative than a temperature of 00C.

**Explaining Water Potential**

Pure water has the highest water potential, because there is a high concentration of water molecules that are completely free to move about. When a solute such as sugar is dissolved in water there are proportionally fewer water molecules to move about and the water potential is lowered.



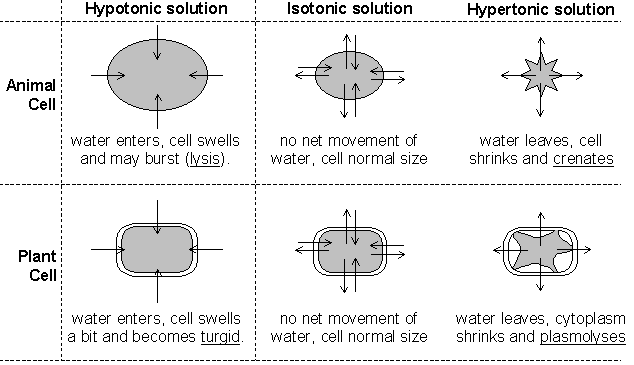
if you look at the diagram above on the left hand side and right hand side of the membrane there are probably the same number of water molecules. However, on the left hand side where there are fewer solute molecules there are more water molecules free to move, therefore the water potential on the left hand side is higher than that on the right hand side.

**Cells and osmosis**.

The concentration of the solution that surrounds a cell will affect the state of the cell, due to osmosis. There are three possible concentrations of solution to consider:

* Isotonic solution a solution of water potential (or concentration) equal to that of a cell
* Hypertonic solution a solution of lower water potential (or concentration) than a cell
* Hypotonic solution a solution of higher water potential (or concentration) than a cell

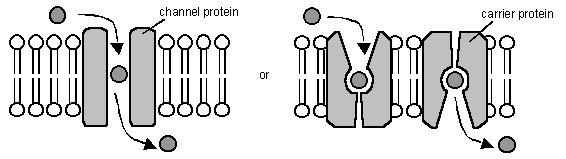
The effects of these solutions on cells are shown in this diagram:



These are problems that living cells face all the time. For example:

* Simple animal cells (protozoans) in fresh water habitats are surrounded by a hypotonic solution and constantly need to expel water using contractile vacuoles to prevent swelling and lysis.
* Cells in marine environments are surrounded by a hypertonic solution, and must actively pump ions into their cells to reduce their water potential and so reduce water loss by osmosis.
* Young non-woody plants rely on cell turgor for their support, and without enough water they wilt. Plants take up water through their root hair cells by osmosis, and must actively pump ions into their cells to keep them hypertonic compared to the soil. This is particularly difficult for plants rooted in salt water.

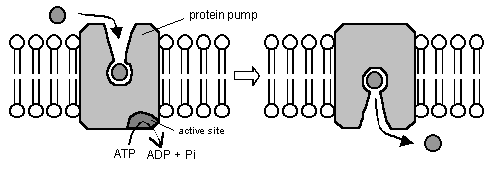
**3. Facilitated Diffusion.**



Facilitated diffusion is the transport of substances across a membrane by a trans-membrane protein molecule. The transport proteins tend to be specific for one molecule (a bit like enzymes), so substances can only cross a membrane if it contains the appropriate protein. As the name suggests, this is a passive diffusion process, so no energy is involved and substances can only move down their concentration gradient. There are two kinds of transport protein:

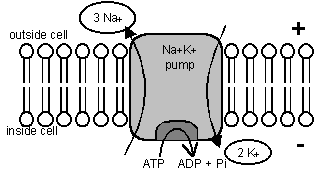
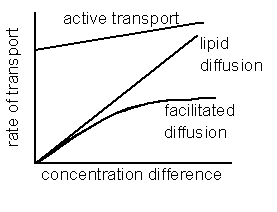
* Channel Proteins form a water-filled pore or channel in the membrane. This allows charged substances (usually ions) to diffuse across membranes. Most channels can be gated (opened or closed), allowing the cell to control the entry and exit of ions.
* Carrier Proteins have a binding site for a specific solute and constantly flip between two states so that the site is alternately open to opposite sides of the membrane. The substance will bind on the side where it at a high concentration and be released where it is at a low concentration.

### 4. Active Transport (or Pumping).



Active transport is the pumping of substances across a membrane by a trans-membrane protein pump molecule. The protein binds a molecule of the substance to be transported on one side of the membrane, changes shape, and releases it on the other side. The proteins are highly specific, so there is a different protein pump for each molecule to be transported. The protein pumps are also ATPase enzymes, since they catalyse the splitting of ATP to ADP + phosphate (Pi), and use the energy released to change shape and pump the molecule across the membrane. Pumping is therefore an active process, and is the only transport mechanism that can transport substances up or against the concentration gradient.

**The Na+/K+ Pump.** This transport protein is present in the cell membranes of all animal cells and is the most abundant and important of all membrane pumps.



The Na+/K+ pump is a complex pump, simultaneously pumping three sodium ions out of the cell and two potassium ions into the cell for each molecule of ATP split. This means that, apart from moving ions around, it also generates a potential difference across the cell membrane. This is called the membrane potential, and all animal cells have it. It varies from 20 to 200 mV, but it is always negative inside the cell when a cell is at rest. In most cells the Na+/K+ pump runs continuously and uses 30% of all the cell's energy (70% in nerve cells).

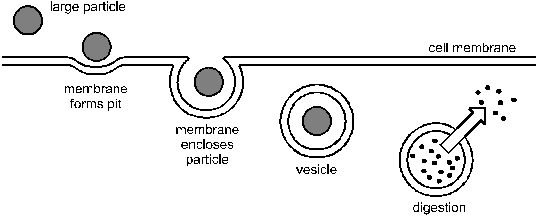
**Rates of Transport Across the Membrane**

The rate of diffusion of a substance across a membrane increases as its concentration gradient increases, but whereas lipid diffusion shows a linear relationship; facilitated diffusion has a curved relationship with a maximum rate. This is due to the rate being limited by the number of transport proteins. The rate of active transport also increases with concentration gradient, but most importantly it has a high rate even when there is no concentration difference across the membrane. Active transport stops if cellular respiration stops, since there is no energy.

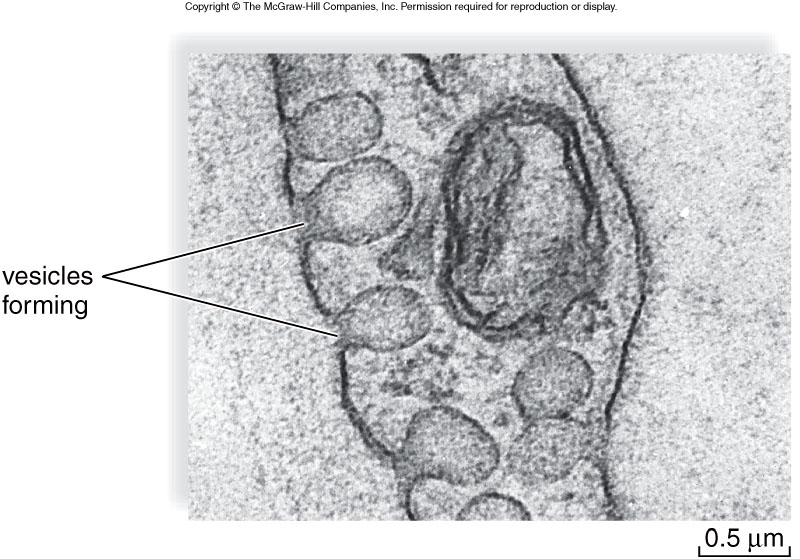
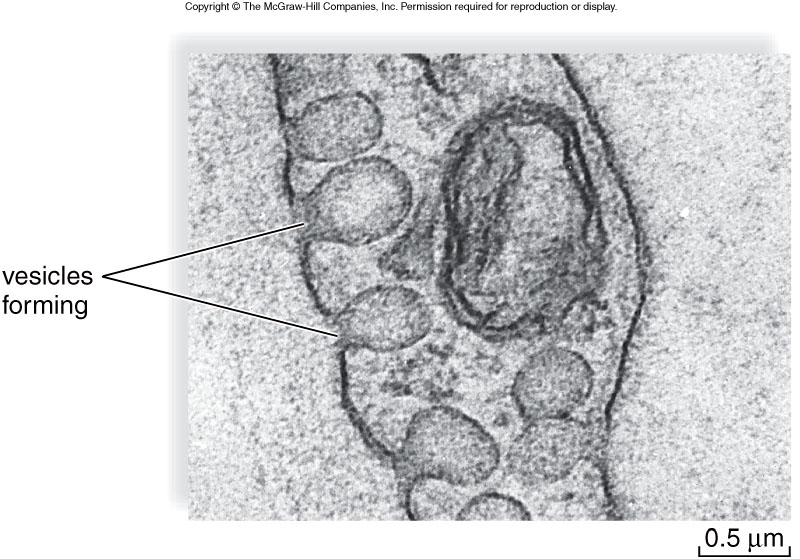
### 5. Endo and Exocytosis

The processes described so far only apply to small molecules. Large molecules (such as proteins, polysaccharides and nucleotides) and even whole cells are moved in and out of cells by using membrane vesicles.

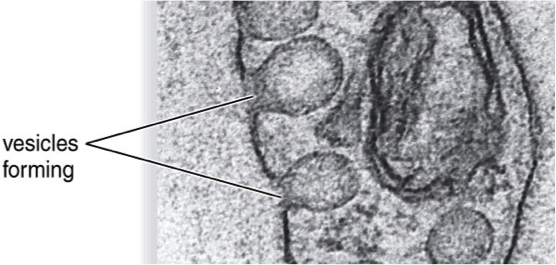
* **Endocytosis** is the transport of materials into a cell. A fold of the cell membrane encloses materials; this then pinches shut to form a closed vesicle. Strictly speaking the material has not yet crossed the membrane, it is usually digested and the small product molecules are absorbed by the methods above (facilitated and simple diffusion). When the materials and the vesicles are small (such as a protein molecule) the process is known as pinocytosis (cell drinking), and if the materials are large (such as a white blood cell ingesting a bacterial cell) the process is known as phagocytosis (cell eating).



* **Exocytosis** is the transport of materials out of a cell. It is the exact reverse of endocytosis. Materials to be exported must first be enclosed in a membrane vesicle, usually from the RER and Golgi body. Hormones and digestive enzymes are secreted by exocytosis from the secretory cells of the intestine and endocrine glands.



Sometimes materials can pass straight through cells without ever making contact with the cytoplasm by being taken in by endocytosis at one end of a cell and passing out by exocytosis at the other end.



**Summary of Membrane Transport   - Please complete**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Method** | **Uses energy** | **Uses proteins** | **Specific** | **Controllable** |
| Lipid Diffusion |  |  |  |  |
| Osmosis |  |  |  |  |
| Passive Transport |  |  |  |  |
| Active Transport |  |  |  |  |
| Vesicles |  |  |  |  |

**Questions**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **1. How does active transport**   1. **Resemble** 2. **Differ from facilitated diffusion?**   **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**  **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**  **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**  **2. The data in the table below show the relative uptake of glucose and xylose (a 5 carbon sugar) from living intestine and from intestine that had been poisoned with cyanide. Cyanide greatly reduces the availability of ATP. Discuss these data.**   |  |  |  | | --- | --- | --- | |  | **Relative rate of uptake by intestine** | | | **Sugar type** | **Without cyanide** | **With cyanide** | | Glucose | 100 | 28 | | Xylose | 18 | 18 |   **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**  **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**  **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**  **3. What factors will affect the rate of active transport?**  **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**  **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**  **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_** |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **4. What do diffusion and osmosis have in common?**  **A. They only happen in living cells.**  **B. They require transport proteins in the membrane.**  **C. They are passive transport mechanisms.**  **D. Net movement of substances is against the concentration gradient.**  **5. What does facilitated diffusion across a cell membrane require?**   |  |  |  |  | | --- | --- | --- | --- | |  | **A pore protein** | **ATP** | **A concentration gradient** | | A. | yes | no | no | | B. | no | no | yes | | C. | yes | no | yes | | D. | no | yes | no |   **6. What is the difference between simple diffusion and facilitated diffusion?**   |  |  |  | | --- | --- | --- | |  | **Simple diffusion** | **Facilitated diffusion** | | A. | Rate decreases with increasing concentration gradient | Rate increases with increasing concentration gradient | | B. | Faster movement of molecules | Slower movement of molecules | | C. | Always involves a membrane | Never involves a membrane | | D. | Uses any part of a membrane | Uses channels in the membrane |   **7. Which process allows the movement of molecules that are too large to enter through a cell surface membrane?**  Aactive transport  B endocytosis  C exocytosis  D facilitated diffusion  8. Which of the following is a feature of exocytosis but **not** endocytosis?  A. Shape changes of a membrane  B. Vesicle formation  C. Use of ATP  D. Secretion  9. Cells in the adrenal gland produce the hormone epinephrine and store it in vesicles. To release epinephrine these vesicles are carried to the plasma membrane and fuse with it. What process is occurring?  A. Expulsion  B. Exchange  C. Excretion  D. Exocytosis |